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SUPERCONDUCTIVITY: A CHANGING R&D SCENE IN GERMANY

R.A. Hein*

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*Naval Research Lab., Washington, DC

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Most of the German research and development associated with superconductivity is centered at the Institut für Experimental Kernphysiks at the Kernforschungszentrum in Karlsruhe and at Siemens AG Research Laboratories in Erlangen with some basic physics and materials studies at various universities and institutes. This report discusses the present status of research and development in superconductivity and remarks on the history, personnel, and outlook of the various programs in these German installations.

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SUPERCONDUCTIVITY: A CHANGING R&D SCENE IN GERMANY

The late 1960's and early 1970's was a period of expansion for German R&D activities in the area of superconductivity. Funds made available through the Bundesministerium für Forschung and Technologie (BMFT) and by the Deutsche Forschungsgemeinschaft (DFG) led to the establishment of new efforts and institutions. For several low-temperature physicists this occurred at a most opportune time for in the USA R&D efforts in superconductivity, especially in California based companies, was on a decline. Thus, today it is not uncommon to find in German research institutes German scientists who had spent from five to ten years working in the USA.

When this writer visited Germany in 1970-71, R&D in superconductivity presented a very bright outlook. Prof. W. Buchel of the University of Karlsruhe was on extended leave to the Kernforschungsanlage, Jülich to start a superconducting materials effort which would supplement ongoing application efforts in the area of controlled nuclear fusion. The Max-Planck Institut für Plasmaphysik, Garching (MPI) was also expanding its efforts in superconducting technology. The Kernforschungszentrum, Karlsruhe (KFK) was expanding its efforts in materials research and developing large scale superconducting prototypes such as the proton linear accelerator. Siemens AG in Erlangen had very active superconducting materials and applications programs involving basic studies and prototype developing work. This latter work was concentrated on dc and pulsed magnets for high energy physics and on superconducting transmission lines. Work directed towards magnetic levitation for high speed ground transportation systems was in the proposal stage.

The main impetus for the magnet development work was the belief or hope that the proposed new proton synchrotron for CERN would use superconducting magnets (see ESN 24:12:395, 25:4:124, 25:4:126, 25:4:89). In fact, one had a very active international collaboration between the Kernforschungszentrum, Karlsruhe, Rutherford High Energy Physics Laboratory, UK, and CEN, Saclay, France, known as the Group for European Superconducting Synchrotron Studies, GESSS. This proposed system was of great interest to magnet fabricators and suppliers of superconducting materials, for one was talking of about one thousand identical magnets. However, with the decision, circa late 1972, not to use superconducting magnets in the new CERN synchrotron the bottom fell out of the pulsed field magnet market. For technical reasons other proposed uses of superconducting magnets in the area of plasma physics have also been abandoned (See G. Bogner-NATO Conference Report in Superconducting Machines and Devices, Editors S. Foner and B.B. Schwartz, Plenum Press 1974). These adverse decisions plus a cutback in funds from the BMFT and DFG has put an end to the expansion of superconducting applications work and, in fact, has led to an overall decrease in the size of the efforts and a concentration of the work to two laboratories. Many of the superconducting aspects of the work at the KFK and MPI (Garching) concerned with controlled nuclear fusion and magneto-hydrodynamical generators has either been curtailed and all of this work is now at KFK. Siemens AG works closely with the KFK and also has the only significant industrial effort in applied superconductivity.

Thus, today visits to the Institut für Experimental Kernphysiks (IEKP) at the KFK and to Siemens Research Laboratories at Erlangen will expose one to most of the ongoing german efforts in R&D concerned with superconductivity. (Excluded from this statement is the more basic materials work and basis studies of the mixed state in superconductors which is being performed at various universities and institutes throughout Germany.) In view of this, I believe, it is of interest to briefly outline the programs at these two institutions.

The IEKP is one of fourteen institutes making up the Kernforschungszentrum at Karlsruhe which is established in 1956 with 30% funding from the Federal Republic, 20% from the State of Baden-Württemberg and 50% from industrial sources. In 1959 operation of the center passed into the hands of Gesellschaft für Kernforschung of Karlsruhe (GFK). Like most of the large research establishments of the Federal Republic, GFK is organized as a limited liability company i.e., GmbH. Since 1963 there are only two stockholders, the Federal Republic and the State of Baden-Württemberg. They support the GFK in a 9:1 ratio. Total expenditure of the GFK in 1974 amounted to 362 million DM. I don't have exact figures but I estimate that direct funding for GFK in 1976 by the Federal Republic via the BMFT is 230 million DM, i.e., about 6% increase over 1975. Thus, even considering the state support, one sees that additional funds must be obtained via grants from industry and from the government for special projects.

The IEKP is made up of three parts; IEKP-I is actually involved with experimental nuclear physics and will not be discussed. IEKP-II, headed by Prof. Dr. Anselm Citron, is concerned with the application of superconducting structures (rf cavities) to a proton linear accelerator and the construction of superconducting rf separators for the Omega spectrometer at CERN. This work is a very intimate collaborative effort involving both IEKP-II and the Solid State Division of Siemens Research Laboratories at Erlangen.

The superconducting accelerator has been discussed in several reports, therefore, I will not go into many details. The first stages of this accelerator employ superconducting Nb helics operated at 90 MHz. Each helix section consists of a Nb "shield can" or tube 0.6 m long and 0.2 m I.D. Mounted inside this shield are several half wavelength helices.

At Karlsruhe one had the pioneering work with the effects of electropolishing and anodizing of the Nb surfaces which led to their success in overcoming many of the rf breakdown effects which had limited the usefulness of earlier devices. After the helical structures accelerate the protons (1.4 MV/m) to say six MEV, they pass into a drift tube (Alvarez type). These resonators will operate at 720 MHz and should produce an acceleration field of 3 MV/m. Initially these resonators used Nb as the superconducting material but more recent experiments with Nb_3Sn plated cavities show good promise. This work is being done at Siemens (see below). In addition to this "hardware" oriented work there is an active group concerned with improving our basic knowledge about the rf properties of "real" surfaces and interfaces.

IEKP-III, headed by Prof. Dr. Werner Heinz, has ongoing efforts in both basic and applied superconductivity. Dr. Komarek is in charge of the "project" research. Here one finds work going in various application areas in keeping with the changed programs of the GESSS laboratories. Since the acronym was so good but the superconducting synchrotron is out, the acronym now stands for Group of European Superconductivity Systems Studies.

The applied project headings and key personnel are:

(A) Magnet Development for High Energy Physics-Turowski, Ardent, and Fessler - This work is concerned with pulsed superconductivity magnets. Progress has been hampered by magnet "training" effects, as well as the problems of ac losses. At Karlsruhe considerable success in reducing the training problem in a dipole magnet has been achieved by the use of strong aluminum rings shrunk onto the magnet. Their success with this magnet, which produced a peak dc field of 5.3T and a pulsed field of 5T (5 second rise time), has paved the way for a new dipole magnet which may be suitable for mechanical rotation. This latter feature will allow one to look at the problems associated with superconductive ac generators. (See CERN Courier Sept 1975.) There is also considerable activity associated with dc superconductivity magnets for linear accelerators. Here the interest lies in quadrapole magnets of high fields and short axial lengths for use as focussing magnets. Quadrapole magnets are also being constructed for use at CERN with the hyperon beam of the 400 GEV machine. Plans call for their installation at CERN by mid 1976.

(B) Superconducting machinery and its associated cooling problems-Koefler, Hofmann, and Turowski - I have no details of this work but apparently the group has a small contract with Siemens to look into the cryogenic problems associated with rotating machinery.

(C) Fusion reactor magnets and energy storage and transfer systems-Krauth, Arendt, Dustman, and Ulbricht - Here the work seems to be centered around the Tokamak design, and is done in association with the Max-Plank Institut für Plasma Physik at Garching. I gather their main interest lies in the pulsed poloidal field system of the Tokamak system and its associated energy storage and transfer systems. These latter systems are being developed at IEKP-III. Results with two 15 KJ superconducting storage coils linked by a superconducting switch were sufficiently encouraging so that they are now building a 100 KJ storage system. The switch for the 15 KJ system, which is driven normal by a current greater than the critical current, was designed for 2000 amperes and a switching time in the 10 microsecond region. The switch used multifilamentary NbTi in a CuNi Matrix and consists of two noninductively wound flat spirals on disks connected in series (O.D. of 40 cm). They are now working on the 100 KJ system switch which will consist of a stack of forty such noninductively wound spirals or disks with a switching time of 10 milliseconds or less. Note that if one discharges or transfers 50 KJ in 10^{-3} second the switch is rated at 50 MW. I gather things are moving ahead with this project and that the switch efficiency, while not as high as one would like, is deemed acceptable to study the properties of high current-high voltage (10^4-10^5V) systems in a cryogenic environment.

(D) Coil and magnet fabrication-Brunner and Specking

(E) Cryogenic techniques-Katheder, Krafft and Kehrmann - These projects are quite similar to what one finds in many governmental and industrial laboratories throughout the world. This is particularly true with regard to the magnet work where one worries about the long time integrity of the windings, training effects, etc. The cryogenic part has a somewhat unique aspect in that one has at Karlsruhe, two huge refrigeration plants-about 350 watts of refrigeration at 1.8°K. Linde built one of the systems and the Karlsruhe people speak highly of this system. The other system, which for political reasons had to be built by a second company, was built by Messer-Griesheim, who has experience with liquid O_2 and N_2 plants. The Linde system uses turbines for both the 75K and 10K stages while Messer-Griesheim used a four cylinder Phillip Kryogenerator for the 75K stage and a piston expander at the 10K stage. After four years of running the Linde plant (1971-1975) personnel deemed it quite a success. Designed for 300 watts it produces 380 watts at 1.8K and has been operated at 1.8 and 4.2K for a total of 13,000 hours. The Messer-Griesheim system was only accepted in 1974.

It is felt that the system still needs improvements in terms of reliability. However, the Messer-Griesheim system is the more efficient, 13.6% Carnot at 1.8K while the Linde system is 8.6%. The main users of the Linde system are the superconducting "linac" project and the projects concerned with the rf separators and pulsed magnets. It also supplies liquid helium (about 100,000 l/yr.) for the entire center.

(F) Superconducting cables and high voltage breakdown-Krauth, Mauer, and Lehrman - This work supplements the Siemens effort with superconducting transmission lines.

(G) Activities in the use of superconducting magnets for magnetic separation of ores and for medical application such as guiding of catheters, etc.-Jungst, and Ries - I gather the ideas and concepts of applying superconducting magnets to medical research are quite akin to those being worked on at MIT in the USA. In all this group of project scientists under Dr. P. Komarek numbers about eighteen.

The fundamental research efforts of IEKP-III are in the hands of Dr. B. Obst. This group is smaller than the applied one. A list of activities and personnel are:

(A) Studies of the intermediate mixed state-Obst - Here one uses the technique of Trauble and Essman, in which one decorates the surface of the superconductor with ferromagnetic iron particles (100Å). These particles are attracted to the flux lines penetrating the mixed state. A carbon replica technique is used for viewing the "flux-line lattice" via an electron microscope. By studying the flux line lattice as functions of sample inhomogenities, physical defects and thermal pulses, one hopes to gain information about pinning effects.

(B) Studies involving technically important superconducting materials such as: the dependence of the critical current density on the magnitude and orientation of an applied magnetic field-K.P. Jungst; pinning effects and internal local magnetic fields-Kupfer; flux-flow properties-Meier-Hermer; thin film superconductors (sputtered, etc.) and pinning in Nb_3Sn-W. Schauer; effects of neutron irradiation (related to fusion magnets)-Seibt.

(C) Basic programs such as: theoretical studies concerning our understanding of the factors which determine T_o-Ries, and Winter; pressure effects studies and T_o and H_c, especially of the superconducting hydrides-Dietrich.

(D) Mechanical properties of superconductors and their role in "training" effects-Schmidt; and mechanical and thermal properties of resins and reinforced epoxies-Hartwig - In regard to this latter item I was surprised to read (CERN Courier, Sept 1975) that the Rutherford group has revived their old concept (see ESN 25:4:126) of wax impregnation as a means of potting a coil with a material which cannot store very much "strain" energy. The basic group at IEKP-III numbers nine full time scientists and two who share their tie with the project oriented work mentioned above.

I would be remiss if I left the reader with the idea that all work concerned with superconductivity is done in the IEKP, for in the Institut für Angewandte Physik one has a very excellent program in ion-implantation of superconductors. This work is under the leadership of Dr. O. Meyer. Here one finds a very modern ion implantation facility which appears to be dedicated to the study of the effects of T_o of known superconductors of various ions implanted in the superconducting host. Both chemically active and inert ions are used to distinguish between radiation damage and other effects in the enhancement or decrease of T_o in elements, alloys and intermetallic compounds. They find that implanting Molydenum (T_o = 0.92K) with N+ and C+ ions increases T_o with a maximum in the T_o versus dosage plots of 7^oK occurring for dosages of about 5×10^{17} ions/cm^2. Meyer *et al.* believe this enhancement is not due to the formation of high T_o compound, but feel that the stabilization of dislocations which ultimately effects the electronic density of states at the Fermi level must be playing a significant role.

The largest industrial effort in Germany, is that of Siemens AG, with its major effort being that of its Research Center in Erlangen. It was in 1959 that Siemens decided to start construction of a large research center about 15 km from the town of Erlangen. Within four years the installation was a reality. The function and purpose of the Research Center is to integrate all branches of science and technology so that Siemens' engineers can offer their worldwide customers an optimum solution of their problems. At tne Research Center one finds a park-like atmosphere with the Plasma Physics, General Physics and Chemistry buildings occupying the central area. The Research Center also contains a Radio-Chemistry building, Reactor Development Complex, Computer Center, Development Laboratories and various service related buildings.

R&D concerned with superconductivity is concentrated within the Solid State Physics Division, headed by Dr. Rolf Gremmelmaier. Dr. Pfister heads up the basic work on materials while Dr. G. Bogner heads the project oriented efforts.

The basic and applied materials work has changed quite significantly over the past five years. At the start of this decade, the applied materials work at Vacuumschmelze, Hanau, Germany, a subsidiary of Siemens, was committed to the NbTi technology and had the task to fabricate the NbTi conductors for the BEBC (Big European Bubble Chamber). This project was successfully completed in the early 1970's. Meanwhile, the basic work at Erlangen was devoted to studies of the A15 compounds (A. Muller) and to the simultaneous occurrence of superconductivity and ferromagnetism in $CeRu_2$ based alloys (M. Wilhelm). Muller, a physical chemist, had been very active in studies aimed at elucidating metallurgical factors responsible for the high T_o which occurs in the binary and ternary A15 intermetallic compounds. B. Hillenbrandt and H. Vogt, both physicists, carried out the cryogenic tests of the materials i.e., T_o, J_c, shielding effects etc. Muller also was working with sintered Nb_3Sn in order to find a material suitable for superconducting magnetic lenses for use in electron microscopes.

Over the years the emphasis has shifted away from basic studies relating to T_o, to more practical problems of how does one make useful conductors out of the A15 compounds. The goal set by the applied projects was to develop a conductor capable of a critical current density J_c of 10^5 A/cm^2 in a transverse magnetic field of 5T (T = tesla). Muller worked with Nb_3Al and $Nb_3(GeAl)$ while Wilhelm and Ziegler attacked V_3Ga and Nb_3Sn respectively.

While Muller perfected a two-step process to produce continuous length of these A15 layer conductors on a Nb wire substrate he could not obtain the required overall J_c value (Jour. Less Common Metals 42 29 (75).). Wilhelm devoted his efforts to the solid state diffusion technique to prepare multifilamentary conductors of V_3Ga but today he is solely involved with the Nb_3Sn work which has reached that point of development where personnel at Vacuumschmelze have perfected industrial fabrication techniques.

Dr. Wilhelm discussed the multifilament program with me and I was impressed with the amount of work he had done on V_3Ga multifilamentary wires. This work was started as a result of Tachikawa's report at ICEC-3, Berlin 1970. Following this conference Wilhelm drew his $CeRu_2$ work to a close and initiated studies of the growth of V_3Ga layers via the solid state diffusion technique and passed on to multifilamentary V_3Ga wire via this same technique. Since this technique is described in several low temperature conference proceedings, I will only say that in essence one inserts one or more vanadium rods (cores) into one or more holes drilled into a copper-gallium (10-18%) ingot (matrix). Employing a few tricksof-the-trade one swages and draws this composite to the desired diameter and subjects it to a temperature of (550-900°C). The Ga diffuses out of the copper and reacts with the vanadium to form the A15 phase of the V-Ga system at the interface. Today, they are concentrating on making Nb_3Sn in an analogous manner. There are several reasons for this but I only want to elaborate on one of these. To the physicist and/or metallurgist who wants to quote large numbers for the critical current densities, J_c, of multifilament wires, he divides the measured critical current, I_c, of the conductor by the cross sectional area of the superconductor present in the composite conductor $J_c = I_c/A^{sc}$. The engineer who uses the wire, however, is interested in one number only and that is the overall critical current density i.e., I_c/area of the composite i.e., $J_c^{o} = I_c/A^{o}$. One can express these parameters as follows:

$$I_c = J_c A^{sc} = \frac{J_c A^{o}}{\alpha_{s1}+1}$$

Here

$$\alpha_{s1} = \frac{A^{o}-A^{sc}}{A^{sc}} = \frac{R^2}{n(2rd + d^2)} - 1$$

where R = radius of the composite conductor, r = radius of unreacted core, d is the layer thickness of the A15 phase and n is the number of filaments present in the composite. From an engineering point of view it is useful to introduce another parameter $\alpha = A^{matrix}/A^{cores}$

where

$$\alpha = \frac{R^2}{nr^2} - 1$$

Therefore, one has

$$\alpha_{s1} = \frac{R\sqrt{\alpha+1}}{\sqrt{n}d(2-d/r)} - 1$$

Thus, to maximize I_c one sees that he must minimize α_{s1}. Hence, for a given α (set by other considerations) one wants to maximize n, d and minimize R.

Now Wilhelm found two things which were not good for the V_3Ga. (1) J_c decreases as d increases and (2) if the "thickness" of the Cu + Ga matrix was less than about 0.2 mm one could not produce layers of the A15 phase much in excess of 4 μm no matter how long one keeps the system at elevated temperatures. He also noted that as the reaction temperature is increased to decrease the reaction times, T_o fell. These considerations put restrictions on the parameters α, d, r, and R one can use to fabricate a useful conductor of $J_c = 10^5 A/cm^2$ at B = 5T. Wilhelm and coworkers at Vacuumschmelze have made multifilament wire with α = 1, d = 1.5 microns, R = 200 microns and n = 60. (Zeitschrift für Naturforschung 27, 1462 (72)). This conductor exhibits a J_c^o of about 4 x $10^4 A/cm^2$ (author estimate) at 5T and thus fell short of the design goal.

Wilhelm devised ways to get around the apparent limitation on the formation of thicker layers - but just about that time (1974) the emphasis shifted to Nb_3Sn. Dr. Ziegler had been working on Nb_3Sn grown from the vapor phase, but in 1974, they decided to try the solid state diffusion technique. Early work showed that the A15 phase of the Nb-Sn system prepared in this manner did not show the problem of growth rates, etc. encountered with the V-Ga system. Thus, the decision to concentrate on Nb_3Sn. In one year they produced conductors with several thousand filaments (Hillman & Springer, Siemens Zeitschrift, Nov., 1975). I believe they are using a basic unit of 61 filaments and 19 filaments to produce conductors with 61 x 61 = 3721 and 85 x 19 = 1615 filaments. The best J_c^o value is for a 3721 filament conductor of 0.3 mm O.D., α = 4 which was reacted at 750°C for 24 hours. This value is 1.8 x $10^5 A/cm^2$ for B = 5T, a value quite acceptable to the applied scientists. The basic work at Erlangen is supported by Siemens while the work at Vacuumschmelze is at least 50% funded by the BMFT.

Within Dr. Pfister's group there is work going on in devising a simple means to easily check the quality of the wires being produced. They are working on a scheme which employs a "Hall" probe which responds to the magnetic field produced by the shielding currents induced in the wire as it is passed through a magnetic field at constant speed. Thus, the wire is continuously passingby the stationary Hall probe. Any flaw or weak spot (low J_c) in the wire produces a change in the Hall probe output which is recorded on a strip chart recorder.

I was particularly impressed by Drs. Hillenbrant's and Wohleben's discussions with regard to high Q Nb_3Sn cavities. Their interest lies in the rf cavities for the proton linear accelerator at IEKP-II. Presently, this prototype uses Nb cavities and to obtain the required Q's of 10^{10} one must operate at 1.8K. Another major consideration is the magnitude of the surface magnetic field at which losses lead to a serious drop in Q. It was originally believed that this value of field would have H_{c1}, the lower critical magnetic field, as its upper limit. For this reason Nb (T_o = 9.2K) with its B_{c1} being approximately 0.16T or so was preferred over Nb_3Sn (T_o = 18.8K) which has a B_{c1} of approximately 0.02-0.03T. One now argues that at X-band frequencies (9.5 GHz), B_{c1} is not the important parameter for at these frequencies the field changes too rapidly for flux lines to form and enter the specimen. Hence, if one doesn't have flux lines present (i.e., no trapped flux) the field at which Q drops is B_c^{ac} which is considerably greater than B_{c1}. Therefore, one should in principle, be able to use Nb_3Sn to fields almost as high as that observed with Nb where B_c^{ac} is approximately 0.16T.

The trick, of course, was to find a way to prepare cavities with a smooth thin layer of Nb_3Sn. They tried various schemes and now do the following: they start with an electro-polished Nb cavity and evaporate Sn on the interior surfaces. This is done at 1050°C at which temperature the A15 phase of Nb-Sn is formed. The final layer of "Nb_3Sn" is 2 to 3 μm with average grain sizes of 2 to 3 μm. Such cavities of dimensions 41 mm x 41 mm have been operated at IEKP-II. For the TE_{011} mode they obtained, at 4.2K, B_c^{ac} of 0.10T and a Q of 2 x 10^9. I believe this development will have far reaching effects on the rf applications of superconductors.

The applied effort at Siemens, Erlangen is under the direction of Dr. G. Bogner. Major interests of this rather large group (about 40 people) are superconducting solenoids, superconducting transmission lines (i.e., cables), superconducting levitation for high speed trains and superconducting rotating machinery. Five years ago, the main emphasis seemed to lie in the area of superconducting solenoids whereas today one finds that the transmission lines and superconducting trains are the "big" projects. However, I believe it is still true that superconducting solenoids are the only commercial product of the group. So this area is not being ignored.

Due to the highly competitive commercial market and the ever changing technology of material preparation, the superconducting magnet business is apparently not a very lucrative one. Siemens sells about twenty solenoids a year to research laboratories and each magnet has to meet different and exacting specifications which require special winding techniques. Thus, if any unforseen trouble develops such as "degradation," etc., the company may well finish with a net loss upon the sale of the final solenoid.

The fact that synchrotron magnets operate under pulse conditions brings up the problem of ac losses in commercially available superconductors. Siemens has an up-to-date test facility for measuring ac losses in such superconductors and have their own facility for fabricating superconducting materials at Vacuumschmelze, Hanau. The ac studies are carried out in close cooperation with the group at Karlsruhe as noted above. Since the field sweeping rates required by synchrotron magnets are about 5T/sec ad the tolerable ac losses are only a few milliwatts per cm^3 of conductor, Siemens has done a detailed study of the ac losses (0.5 to 4 Hz) of various commerically available filamentary composites. They construct test solenoids of the conductor under examination and measure the ac losses both electrically and calorimetrically as functions of (1) normal matrix material, i.e., copper versus copper nickel (2) diameter of the filaments, ratio of matrix to superconducting material, pitch of twist given to the conductor, type of winding employed i.e., cooling channels versus vacuum impregnation (potting), etc.

The 1973 decision not to use superconducting magnets in the new CERN accelerator, means that this type of work is no longer of high priority, but I'm sure Siemens has not completely curtailed this work and hopes that future decisions will make it possible to draw on this back-log of information, data and know-how. I am not fully apprised of the current state-of-the-art but I gather that the ac losses with the best NbTi and Nb_3Sn composites may still be a factor of 10 larger than the design goal of a few milliwatts per cm^3 of conductor.

Progress with respect to the prototype development of a three phase superconducting transmission line has, in this writer's opinion, not been very impressive. In 1970 one had a 6-meter test bed today one has a 28-30 meter test bed, consisting of a single phase line. It consists of a rigid outer shell into which a flexible conductor with Nb as the superconducting component is pulled. Bogner *op. cit.* reported that tests for ac operation at 120 KV and 12 KA were planned for 1974. To date these tests have not been performed. But currently there is a sense of urgency and consequently much activity. This is because the BMFT which since 1970 has supplied 50% of the funding for this project must make a decision about future fundings. As I understand it, if the tests do not come off successfully no more funds will be forthcoming (1977). If the tests are successful, there are still doubts about future funds for the need and economics of superconducting transmission lines is still very much a debatable issue. That this is the situation some ten years after the initiation of serious prototype development program is a source of amazement to the writer.

In the area of superconducting magnets for levitation of high speed ground transportation systems one must be impressed with the advancement made in the size and complexity of the involved hardware. In five years Siemens and its collaborating laboratories have gone from a toy train and a bench sized rotatable aluminum disk to a full scale circular track some 280 meters in diameter and a 12 ton test vehicle (see C. Albrecht *et al.* ICEC-5, May 1974

Kyoto, Japan). This work has been made possible through the favorable decision by the BMFT in 1972 to fund this project. I also believe the Bundesministerium für Verkehr (Dept. of Transportation) has made some financial commitments. To an American who sees the above test track for the first time, there is a tendency to quickly look around to assure himself that he is not at Disneyland. A large circular track tilted at 45° is quite a sight to behold. However, this track and its associated equipment is a well conceived test bed to permit testing of full scale components under actual operating conditions. Dr. C. Albrecht is justifiably proud of their accomplishments to date. The 12 ton test vehicle is equipped with 16 wheels (Starfighter wheels) which permits testing of the linear induction motors and various controls in the "rolling" mode at speeds up to about 200 km/hr. Eight of the above wheels are used for the guidance system. The test vehicle also has two inner magnet platforms designed for the testing of the levitation and guidance magnet systems when operated in the "floating" mode. The prototype magnet systems have been built and tested at the Research Center. They will operate in the persistent mode. As is usually the case, the magnet systems, due to the complexity involved by the on-board requirements, embraced quite a bit of development work. But in modern day parlance all systems are go! The actual tests of the superconducting systems must be completed in the near future. For in 1977 the moment-of-truth arrives for all the competing systems in the German race for a high speed ground transportation system. The Siemens group still has a long way to go, in order to have a "revenue" vehicle ($\geq$100 tons, 500 km/hr) on the Donauried test track (70 km long) by mid 1977. Clearly one has problems other than cryogenic ones, for example, current collection for the linear induction motor.

As alluded to above, Siemens and BMFT equally support an effort to incorporate superconducting magnetic lenses in electron microscopes. Dr. I. Detrich of the München Laboratories, who is in charge of this project, recently published a review article on this work. (I. Detrich *et al.* Cryogenics Dec 1975 p. 691). A. Muller of the Research Laboratories has perfected the fabrication of the sintered Nb_3Sn shields for this work.

From this rather incomplete summary of German R&D in the area of superconductivity, one sees that the Federal Republic still supports a sizable effort at both its own laboratories and at Siemens AG. There have been cutbacks and a reorganization of priorities but by and large, I believe, one can say that fifty years of low temperature physics (helium was liquified in Berlin in 1926) has produced a strong and significant applied superconductivity effort in Germany.